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Oregon Clean Fuels Program Report 2018

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NERC is based at Portland State University in the College of Urban and Public Affairs. The Center focuses on economic research that supports public-policy decision-making, and relates to issues important to Oregon and the Portland Metropolitan Area. NERC serves the public, nonprofit, and private sector community with high quality, unbiased, and credible economic analysis. Dr. Tom Potiowsky is the Director of NERC, and also serves as the Chair of the Department of Economics at Portland State University. Dr. Jenny H. Liu is NERC's Assistant Director and Associate Professor in the Toulan School of Urban Studies and Planning. The report was researched and written by Dr. Jenny H. Liu and Emma Willingham, with research support from Michael Paruszkiewicz and Minji Cho.

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Executive Summary

This report, written by the Northwest Economic Research Center (NERC) of Portland State University with support from the Packard Foundation, is the first in a series designed to assess the economic impact of the Oregon Clean Fuels Program (CFP). Following a discussion of carbon mitigation tools and policies, the body of the report establishes a baseline of infrastructure and regulated parties, followed by presentation and analysis of a set of economic indicator variables expected to influence or be influenced by the CFP. (See p. 5 for a table with all variables and their relevance to the program.)

Low carbon fuel standard (LCFS) programs like the CFP are policies designed to encourage the adoption of low carbon alternative fuels via a market-based regulatory framework, similarly to "cap and trade" policies. In this market, transportation fuel providers offset deficits generated by the production or import of high carbon-intensity fuels by purchasing credits generated by the production of low carbon-intensity fuels. The metric used to describe carbon intensity is grams of carbon dioxide equivalent emitted per megajoule of energy produced (gCO2e/MJ). Carbon intensity levels specified by the Oregon CFP, along with the percent change from the 2010 baseline carbon intensity and percent change required from year to year, are presented in Table 1 below.

Table 1: Oregon Clean Fuels Program Standards in Percentage and Carbon-Intensity Terms[1]

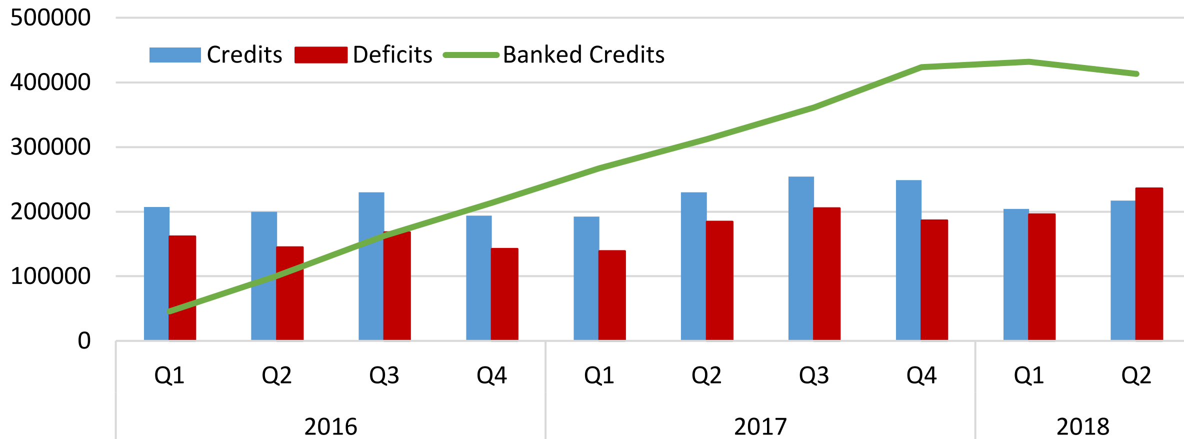
	Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
% reduced	From 2015	0.25	0.50	1.00	1.50	2.50	3.50	5.00	6.50	8.00	10.00
	From prev. year	--	0.25	0.50	0.50	1.00	1.00	1.50	1.50	1.50	2.00
gCO2e/MJ	Gasoline	98.37	98.13	97.63	97.14	96.15	95.17	93.69	92.21	90.73	88.76
	Diesel	99.39	99.14	98.64	98.15	97.15	96.15	94.66	93.16	91.67	89.68

Over the period that the program has been active, credits have exceed deficits in every quarter except for the most recent one (see Figure 1 below). Banked credits, which accumulate when credits exceed deficits in a given period, rose steadily for the first two years of the program as entities overcomplied with the new regulation, before decelerating in 2017Q4 and starting to fall in the first half of 2018 (due to the excess of deficits over credits). This change in the market may indicate that the regulation is beginning to "bind"—that is, that the expansion of current clean fuels facilities and infrastructure may be necessary to meet the carbon intensity pathway going forwards. In other words, the lowest-cost mitigation measures have at this point been taken, and compliance will entail a higher price going forward. Interestingly, the two other such programs currently in existence—California's Low Carbon Fuel Standard and British Columbia's Renewable & Low Carbon Fuel Requirements Regulation—both reached the same turning point within the last year, with deficits exceeding credits for the first time. However,

[1] Oregon Department of Environmental Quality. Clean fuel standards. Retrieved from Oregon.gov/DEQ

additional data points will be necessary to conclude whether this is indeed a continuing trend or a temporary fluctuation.

Figure 1: Credits, Deficits, and Banked Credits by Quarter, 2016Q1-2018Q2[2]



As the program is still relatively near its outset, it is difficult to attribute changes in tracked indicator variables to its impact. However, the ongoing collection and presentation of these relevant series of economic outcome indicators will provide insight into changes as they occur. If the aforementioned change in the balance of credits and deficits indicates that the program is in fact beginning to alter the behavior of regulated parties, said impacts will be more apparent in the near future.

Key changes in the indicators (when available) are briefly summarized below:

- **Regulated parties**: There are currently 154 regulated parties, up from 142 in December of 2017.
- **Refueling infrastructure**: The number of alternative fuel stations in Oregon has grown from 23 prior to the CFP's implementation in 2016Q1, to 87 at the time of writing.
- **Electric vehicle charging stations**: Over the period since implementation, the number of EV charging stations in the state has increased from 87 to 219.
- **Oregon vehicle fleet**: In 2016 and 2017, the Oregon vehicle fleet grew by an average of 2.81% per year (about double the annual average rate since 2010). SUVs grew more, with an average annual rate of 6.99%, and electric vehicles grew most of all, with a 38.8% average growth rate.
- **Fuel consumption**: Over the implementation period, no trend is visible. Alternative fuels comprised between 11% and 13% in all quarters.
- **Fuel pricing**: From 2016Q1 to 2018Q2, fuels derived from oil sources have increased in price, while fuels derived from natural gas have remained relatively steady.
- **Greenhouse gas emissions**: While data for the implementation period is not yet available, both total emissions and emissions from transportation reversed previous downward trends in 2014 and began to climb.

[2] Clean Fuels Program Second Quarter 2018 Data. (2018.) State of Oregon Department of Environmental Quality. Retrieved from Oregon.gov/DEQ

- **Air quality**: Comparing multi-year averages before and after implementation, median air quality (as measured by the Air Quality Index published by the U.S. Environmental Protection Agency) has improved in all monitored counties, with the exception of Wasco.

Project Description

In 2015, the Oregon Legislature passed SB 324, which allowed the full implementation of the Clean Fuels Program (CFP) beginning in January of 2016. The policy requires a ten percent reduction from 2015 levels in the carbon intensity of fuels used for transportation by 2025, with a differentiation between gasoline and diesel (and their respective substitutes). This transition will take place at a rate accelerating from a 0.25% reduction over the 2016-2017 calendar years (the only two-year compliance period) to a 2% annual reduction in the final year, 2025 (See Table 1 on p. 8 for specific reduction percentages and carbon intensity values over this period).

Portland State University's Northwest Economic Research Center (NERC), with support from the Packard Foundation, is developing a system to track changes in fuel and related markets in order to assess the program's impact on the local economy. This report is the first of the series, and so will present data on relevant variables from the program's implementation outset in 2016Q1 through the most recent period for which the variable in question is available. The data presented are organized as shown in Table 2 (p. 5). Regular reports on current trends in these variables will allow relevant parties to assess changes to the economic landscape in response to this program.

Following this introduction, the report provides background in the form of a brief literature review on the Oregon Clean Fuels program, as well as other similar programs, most notably that present in California (p. 6, California summary on p. 13). In the next section, baseline values for chosen variables are presented (p. 15), followed by a series of indicators tracked over the timespan since the program's implementation in the first quarter of 2016 (and in some cases prior to that date), when possible (p. 18). An accompanying fact sheet that provides at-a-glance visualization of chosen economic indicators is available from the authors.

Table 2: Organizational Chart & Relevance of Included Data

Category	Subcategory	Indicator	Relevance
Industry baseline	Registered parties		Shows program participation by traditional and alternative fuel companies
	Refueling infrastructure	Alternative fuel stations	Indicates capital investment related to alternative fuel provision (CFP is designed to encourage investment in alternative fuels)
		Electric vehicle charging stations	Indicates capital investment related to electric vehicle use
Tracked indicators	Vehicle fleet	Fleet by vehicle type	Tracks vehicle types registered in OR prior to and under CFP
		Total electric vehicles registered (including plug-in hybrid vehicles)	Tracks electric vehicle registration (CFP is designed to place a price on high carbon intensity fuels commonly used in conventional vehicles with an internal combustion engine)
	Fuels	Total consumption by fuel type	Shows changes to consumption (CFP is designed to encourage a transition to alternative fuels with lower carbon intensities).
		Fuel pricing for gasoline, diesel, and select alternative fuels	Fuel pricing influences (and is influenced by) the demand for various types of fuel.
	Environmental indicators	Greenhouse gas emissions (GHG)	CFP is designed to reduce GHG emissions.
		Air Quality Index (AQI) values	Reduced transportation emissions may result in improved air quality over the long term.

Background

This section connects Oregon's Clean Fuel Program (CFP) to carbon mitigation programs elsewhere by describing policy goals, structure, and metrics for success. A description of Oregon's program is followed by discussion of best practices for program design, and an overview of low carbon fuel standards implemented elsewhere.

Oregon's Clean Fuels Program

Low carbon fuel standard (LCFS) programs like the CFP are policies designed to encourage the adoption of low carbon alternative fuels via a market-based regulatory framework, similarly to "cap and trade" policies. In this market, transportation fuel providers offset deficits generated by the production or import of high carbon-intensity fuels by purchasing credits generated by providers of low carbon-intensity fuels. Carbon intensity measures carbon dioxide emitted per unit of energy provided from a given fuel source, considering the entire "life cycle" of the fuel source: that is, including every aspect of the fuel's production. It is important to note that this approach is not taken in carbon tax or "cap and trade" programs, lending unique value to LCFS policies. This approach is often termed "well-to-wheels," or "seed-to-wheels" for fuels derived from plant sources. The metric most commonly used to describe the carbon intensity of fuel is grams of carbon dioxide equivalent emitted per megajoule of energy produced (gCO_2e/MJ).

Low-carbon fuel standards are similar to renewable fuel mandates, which specify volume requirements for identified renewable fuels. Both policies are designed to address the transportation industry, which is responsible for a high proportion of overall emissions (26%, according to the EPA[3]). One argument for such policies is that it is important to specifically address transportation, as it is a relatively price-inelastic sector that does not respond as readily to carbon taxes and cap and trade programs in comparison to other areas of the economy (meaning that more firms and individuals would rather pay increased fuel costs than reduce their emissions).[4] However, when there is a mandated increase in the volume of renewable fuels, the corresponding increase in supply due to economies of scale can result in a reduction in price and thus additional increase in demand. According to a 2016 analysis of the US EPA's Renewable Fuel Standard, this "rebound effect" can actually offset the reduced emissions in the production of biofuel relative to gasoline, if the selected biofuels are not at least 60% less emission-intensive than gasoline.[5] In contrast, low-carbon fuel standards both encourage innovation (by not specifying a particular fuel, and rewarding incremental changes to supply pathways) and lessen the rebound effect by not imposing a volume requirement.

The emphasis on carbon intensity over simple fuel type is the factor that differentiates the CFP approach from renewable fuel mandates, and this emphasis is intended to promote the creation and adoption of more sustainable technology. In other words, a low-carbon fuel standard rewards not only use of renewable fuels, but innovations in their production, while avoiding undesirable market distortions caused by the promotion of specific fuel types without regard for carbon intensity, as would be seen

[3] Sources of Greenhouse Gas Emissions. (2017.) Retrieved from EPA.gov.
[4] Gas prices tend to have little effect on demand for car travel. (December 15, 2014). Retrieved from EIA.gov.
[5] J. Hill, L. Tajibaeva, S. Polasky. (2016.) Climate consequences of low-carbon fuels: the United States Renewable Fuel Standard. Energy Policy, 97, pp. 351-353

under a volume-based fuel standard.[6] The most concerning type of market distortion with this type of program is emissions leakage: the effective outsourcing of emissions to nonregulated areas, when fuel buyers simply shift to parties not covered by the regional policy. This leakage can still be a concern under an intensity-based approach like the CFP, but the dilution of price effects lessens the concern considerably (certainly in comparison to straightforward tax schemes), as does the effective subsidization of domestic alternative energy production.[7] Shuffling, or the import of pre-existing alternative fuel supplies in order to meet requirements, is a concern because such cost-saving behavior will give the appearance of reduction without involving any real change, but shuffling still sends market signals that could increase alternative fuel production and innovation (in contrast to leakage, which encourages production of standard energy).[8]

Additionally, using carbon intensity as the metric within the fuel standard approach, rather than outright emissions, is an important distinction—by considering the amount of emissions generated per mile, or per unit of energy, this approach allows for the fact that total vehicle miles traveled, and thus total greenhouse gas (GHG) emissions, increase with the population and level of economic or transportation activity. Targets set at absolute levels would therefore be much stricter than they first appear, because they must offset the natural increase in addition to meeting the reduction target.[6]

While direct use of land and resources has always been considered in such fuel pathways, concern now has shifted to *indirect* land use change (ILUC)—that is, changes that occur in land use for other crops, as a result of increased demand for feedstock crops. While the "direct" carbon intensity of fuel pathways is complex to estimate and values must be continuously updated to reflect new technology and information, appropriate ILUC values are even more challenging, as they vary considerably by region, reflecting differing farming practices, government and policy, and economic climates.[9] However, their importance is undeniable, and all existing low carbon fuel standard policies recognize their importance in calculating carbon intensity.

By specifying only the carbon intensity requirement, fuel standard programs are notably flexible—covered firms can comply by adjusting production methods, producing alternative fuels, or purchasing credits. The sale of credits functions in the market as a subsidy, so while the gross abatement cost can be higher than under alternative carbon mitigation policies (such as renewable fuel mandates or CATs), the net cost is lower, as relevant covered entities can take advantage of the de facto subsidy to offset their costs.[10] However—as is the case with any policy designed to drive technological advancement—these programs rely on innovations that may not yet exist in implementable form. Therefore, while low-carbon fuel standards are an attractive and frequently-considered option, few have been implemented,

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[6] Yeh, Sonia et al. (July 19, 2012). National Low Carbon Fuel Standard: Policy Design Recommendations. Retrieved from SSRN.com
[7] Holland, S. (2012). Taxes and Trading versus Intensity Standards: Second-Best Environmental Policies with Incomplete Regulation (Leakage) or Market Power. Journal of Environmental Economics and Management 63(3), 375–387
[8] Farrell, A. E, & Sperling, D. (2007a). A Low-Carbon Fuel Standard for California, Part 1: Technical Analysis. UC Davis: Institute of Transportation Studies (UCD). Retrieved from escholarship.org
[9] Yeh, Sonia et al. (2016). A review of low carbon fuel policies: Principles, program status and future directions. Energy Policy 97 pp. 220-234.
[10] Yeh et al. (2016)

and those that have are in their nascent stages. Additionally, because technological progress cannot be predicted in any meaningful way, projections of program impacts are by nature highly speculative.

In 2015, the Oregon Legislature passed SB 324, which allows the full implementation of the Clean Fuels Program beginning in January of 2016. The policy requires a ten percent reduction from 2015 levels in the carbon intensity of fuels used for transportation by 2025, with a differentiation between gasoline and diesel (and their respective substitutes). This transition will take place at a rate accelerating from a 0.25% reduction over the 2016-2017 calendar years (the only two-year compliance period, with said 0.25% reduction occurring in each year) to a 2% annual reduction in the final year, 2025. The first two rows of Table 1, below, show the percent reduction from 2015 levels required in total, and the percent decrease required from the previous year, in order to illustrate the accelerating nature of the requirement. Specific required carbon intensity values in gCO2e/MJ for gasoline and diesel are shown in the second two rows.

Table 1: Oregon Clean Fuels Program Standards in Percentage and Carbon Intensity Terms[11]

	Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
% reduced	From 2015	0.25	0.50	1.00	1.50	2.50	3.50	5.00	6.50	8.00	10.00
	From previous year	--	0.25	0.50	0.50	1.00	1.00	1.50	1.50	1.50	2.00
gCO2e/MJ	Gasoline	98.37	98.13	97.63	97.14	96.15	95.17	93.69	92.21	90.73	88.76
	Diesel	99.39	99.14	98.64	98.15	97.15	96.15	94.66	93.16	91.67	89.68

The program operates by allowing regulated entities (fuel producers and importers) to generate credits by producing or importing fuels that meet the carbon intensity standard for a given year, or to purchase credits to offset the production or purchase of fuels that do not meet the carbon intensity standard. Credits are generated on a quarterly basis when a fuel meeting the applicable carbon intensity standard is produced, imported, or dispensed in Oregon, and recorded in the Clean Fuels Program Online System. Deficits are generated when fuels that do not meet said standard are produced, imported, or dispensed. Credits can be bought and sold by regulated entities, including credit aggregators that provide no other service, at market-determined prices. At the end of a year, credits accumulated past the compliance obligation must be retired. If a regulated entity has deficits that exceed credits, all credits held by that entity are retired. At the outset of the program, a two-year compliance period is provided to allow for transition time: credits for 2016 and 2017 must be balanced by the end of the 2017 calendar year, and each year annually going forwards. Fuel provision for aircraft, farm and construction equipment, log trucks, military vehicles, watercraft, and racing vehicles is exempt, and small importers (firms that import less than half a million gallons of transportation fuels per year) are not required to comply.

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[11] Oregon Department of Environmental Quality. Clean fuel standards. Retrieved from Oregon.gov/DEQ

Every three years at minimum, OR Department of Environmental Quality (DEQ) is required to review the methodology for determining the many calculated components of carbon intensity. At the program's outset, estimates from California's Air Resources Board (discussed below, with California's low carbon fuel standard program) adjusted to fit Oregon are approved by OR DEQ for regulated parties. These intensities are termed OR-GREET estimates, after the Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy in Transportation model (GREET). OR-GREET 3.0 is the current model adopted at the end of 2018 by the Clean Fuels Program 2018 rulemaking advisory committee.

In 2018, DEQ introduced a backstop aggregator, the role of which is to account for credits generated via residential electrical vehicle charging. In cases where an electrical utility does not register as a credit generator or designate an aggregator (party which accounts for generated credits), the backstop aggregator can claim any credits that said utility would have generated. For nonresidential charging, if the owner or service provider of the charging equipment and relevant utility company do not register as credit generators, the backstop aggregator is similarly entitled to generate credits.[12] The chosen nonprofit for this role in 2019 is Forth, an organization dedicated to expanding and enhancing electric, smart, and shared transportation.

Within this report, NERC tracked and analyzed a number of indicators in order to assess the success of the program and its impacts within the state. These indicators include fuel prices, vehicle sales by clean fuel type, vehicle fleet changes, credit market price and volume, and available data on relevant employment.

Best Practices in LCFSs and Existing Programs

Currently, there are three major low-carbon fuel standard programs in existence: the European Union's Fuel Quality Directive (FQD), British Columbia's Renewable & Low Carbon Fuel Requirements Regulation (RLCFRR), and California's Low Carbon Fuel Standard (LCFS). Following an examination of best practices summarized from several sources, this section presents a brief summary of each program, including structure and techniques for measuring compliance and impacts.

Best Practices in LCFS Policy

Due to the flexibility of LCFS programs, consideration of the factors that promote high efficiency and low cost is vital. There are challenges behind this analysis, predominately related to a relative lack of data and literature.[13] This report, and the tracking that this project entails, will provide a valuable resource to future researchers. However, in the absence of historical data, theory provides some importance guidance on the elements that contribute to a successful, cost-effective LCFS. Prior to the implementation of California's fuel carbon intensity program, Alexander Farrell and Robert Sperling conducted a two-part analysis of low-carbon fuel standards for the Institute of Transportation Studies at UC Davis. While the first part (which will be discussed below in the section on California's program) established that the intensity reduction goal of the policy is most likely feasible, the second part set

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[12] FORTH. (September 11, 2018). Clean Fuels Backstop Aggregator Workplan. Retrieved from Oregon.gov/DEQ

[13] G.E. Lade, C.-Y.C. Lin. (2015.) The design and economics of low carbon fuel standards. Research in Transportation Economics, 52, pp. 91-99

identifies policy problem areas, and makes recommendations to achieve said goal. Considering the lack of real-world data, these recommendations can be considered best theoretical practices.[14]

Credits: Cap Prices and Banking

Credit prices in LCFS programs are determined by the market—when alternative fuel is abundant, prices are low, and when the market tightens, prices rise. Likewise, when demand for fuel is high, prices rise, and when it falls, credit prices do as well. This price then determines the degree of incentive and disincentive for low- vs. high-intensity fuel production. It is considered a best practice to include a cost containment mechanism—that is, a cap on credit pricing—to protect fuel suppliers in the event of extraordinary market pressures resulting in a credit shortage. Along the same lines, it is considered a best practice to allow firms to bank credits between periods. This has been shown in simulations to lower firm costs by 5-9% and diminish credit price fluctuations.[15] In Oregon's case, credit prices were capped at $200 for 2017, and the cap will be adjusted for inflation going forwards using the Urban CPI for the west coast. Firms are not allowed to bank credits between periods.

Assessment of Carbon Intensity

The method for determining carbon intensity is important as well—three different approaches are possible. First, intensity can be calculated "at the pump," meaning that the amount of energy embodied by the fuel as it enters a vehicle, with no consideration of vehicle type. While relatively simple to conduct, this method misses vehicle efficiency entirely and thus cannot be considered very accurate.

Second, intensity can be calculated per mile, in which case the fuel economy of the vehicle becomes important. This method could be termed "per-mile" intensity: it uses overall vehicle efficiency, which can include factors such as air drag, vehicle weight, and any other conceivable factor that impacts fuel efficiency.

Finally, intensity can be calculated "at the wheel," or per unit of energy produced, accounting only for differences in engine and drive train efficiency. In this case, the unit is "rotations of drive train per unit of energy input." The data for this calculation is considerably less exhaustive, because only this attribute is considered. The previous "per-mile" approach is theoretically the most accurate, as it fully represents the actual emissions produced by a given vehicle running on a given fuel, but is very costly, due to the relative breadth of data required and complexity of the model (both attributes which also increase uncertainty and decrease transparency). Therefore, the "at the wheel" approach is considered superior, as it is more accurate than the first approach and less costly than the second.[16] This is the approach chosen for California's program (discussed in more detail below), and for Oregon's program, which borrows California's intensity estimate methodology with slight location-based variations.

Complete Coverage

Farrell and Sperling recommend that covered entities include all gasoline and diesel producers, and that non-fluid fuel producers be given the opportunity to opt in to the market and produce credits. In future, non-fluid fuel producers might become regulated entities, if market penetration increases. This

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[14] Farrell, A. E, & Sperling, D. (2007b). A Low-Carbon Fuel Standard for California, Part 2: Policy Analysis. UC Davis: Institute of Transportation Studies (UCD). Retrieved from https://escholarship.org.
[15] Rubin, J. et. Al. (2012.) National Low Carbon Fuel Standard Policy Design Recommendations.
[16] Farrell and Sperling (2007a.)

recommendation ensures that the market is covered as completely as possible, increasing the efficacy of the program and avoiding loopholes and distortions. Oregon meets this recommendation for the most part: all producers are covered regardless of fuel type, but there is an exemption from the requirement for parties that import only 500,000 gallons (or less). These "small importers" are free to generate and sell credits on the market, but are still required to register with the state and keep records for the purpose of submitting annual (but not quarterly) reports of credit generation.

Separation of Gasoline and Diesel

Next, the authors recommend that diesel and gasoline be treated separately, due to differences in efficiency that could lead to a shift from one fossil fuel to another: diesel is more carbon-intensive, but diesel engines are more efficient. Increased diesel sales relative to gasoline sales, a predicted occurrence in coming years, would otherwise manifest as a reduction in average fuel carbon intensity without entailing any innovation or movement away from traditional fuel. Oregon has separate compliance schedules for gasoline and diesel emissions, as recommended.

Intensity Reduction Pathways

Finally, there are three different trajectories possible for the emissions reduction schedule: accelerating, decelerating, or constant. In other words, should the amount of annual decrease be largest at the outset, the sunset, or constant throughout? Farrell and Sperling recommend a decelerating schedule that requires steep reductions at the beginning, in order to force firms to take advantage of existing supplies of low-carbon fuel at the outset of the program. This ensures that, after these pre-existing supplies are exhausted, further emissions reductions are representative of actual real world change: they must come from the increased production of renewable fuels, rather than the use of what is already present. However, this is a legislatively difficult proposal, as there are many legitimate stakeholder concerns about the burden this could place on producers, and said authors actually reversed their recommendation based on these concerns in a follow-up report.[17]

A constant pathway has no special merit and exists mostly as a default option; no discussion is included. An accelerating pathway, however, where steeper increases are required as the program progresses, has distinct advantages of its own: it allows for more flexibility during the initial stages, and the prospect of increased stringency further down the road should stimulate increased innovation on a more realistic timeframe. This is the pathway type ultimately recommended, in light of the stakeholder concerns about the decelerating pathway mentioned above, and was in fact selected by both Oregon and California.

Statewide Baseline

Farrell and Sperling recommend a statewide baseline, rather than a requirement for firms to reduce their own emissions 10% from 2010 levels. This avoids penalizing firms that have achieved their lowest-cost emission reductions prior to the implementation of the policy, and ensures that the 10% target will be met despite uncertainty about the composition of the fuel market in the future. This recommendation is followed in both California and Oregon.

[17] Farrell and Perling (2007b)

Other LCFS programs

At the time of writing, there were three other LCFS programs in existence: one in the European Union, one in British Columbia, and the aforementioned in California.

EU Fuel Quality Directive

This policy, implemented in Directive 2009/30/EC, sets the goal of a ten percent reduction in lifecycle greenhouse gas emissions by the end of 2020, in comparison to 2010 levels, and specifies a minimum reduction of six percent directly attributable to increased use of biofuels and alternative fuels. It is emphasized that only the six percent drop should be binding, as the remaining four percent will occur naturally due to other environmental regulations from the UN. Following the Directive's passage in 2009, contention about lifecycle pathway calculations proved substantial enough to instigate a debate that lasted five years, until the Commission proposed GHG intensity default values, to be accompanied by reports from each nation on fuel mix feedstock origins.[18] With the administrative burden shifted away from suppliers, the Directive was accepted. However, member states have been choosing to meet their obligation through a corollary requirement in the Renewable Energy Directive (Directive 2009/28/EC) that stipulates ten percent renewable fuel in the transport sector, rather than by reducing GHG intensity in production, and thus reports from the Commission do not describe changes in fuel intensity. Therefore, while in theory the programs are the same, in practice the credit market is not used.

BC Renewable & Low Carbon Fuel Requirements Regulation

Similarly to Oregon's Clean Fuels Program, the BC RLCFRR (approved in 2008) specifies a ten percent reduction in transport fuel carbon intensity over ten years, from 2010 to 2020. In addition to meeting their obligation by producing alternative fuels, changing production to lower-carbon technologies, or trading credits, firms in British Columbia have an additional option—they can enter into "Part 3 Agreements," which serve as contractual obligations to engage, or encourage others to engage, in actions that have a good probability of enabling emissions reductions via low carbon fuel use more rapidly than if the action had not taken place. Credits are issued for these agreements, and reported agreements reached have been predominately related to the construction of biofuel infrastructure.[19]

Over the first three years of the RLCFRR, firms were required only to report carbon intensity, not actually reduce it. As the RLCFRR accompanied a second piece of legislation that specifies renewable fuel volumes, all covered entities easily achieved the required reductions in carbon intensity. The program report issued in September of 2018, spanning 2013-2017, reports 66 credit transactions over that time, with a total credit volume of 676,627 and an average credit price rising from $169.95 in 2015 (the first year for which average price is reported) to $199.96 in the third quarter of 2018. Net surplus credits are not yet available for 2018, but in 2017, the surplus dipped from positive values in excess of 300,000 to a negative 55,874.[20] This could indicate that the policy is beginning to have an effect on the fuel market.

[18] Fuels Quality Directive (FQD). (2017.) Retrieved from FuelsEurope.eu.
[19] Renewable & Low Carbon Fuel Requirements Regulation. Retrieved from www2.gov.bc.ca.
[20] Low Carbon Fuel Credit Market Report. (October 2018.) Retrieved from www2.gov.bc.ca.

California Low Carbon Fuel Standard

California's program, overseen by the CA Air Resources Board (CARB), also seeks to reduce carbon intensity in transport fuel by ten percent over ten years (2010-2020). Despite early legal challenges, this is the longest-running and best-documented LCFS policy, and thus will be considered at length below, as the best comparison for Oregon's program. Regulated parties are all entities that supply fuel in the state (exempting low-volume suppliers, propane, military, aircraft, and watercraft). Exempt parties may choose to opt-in and produce credits for sale to deficit-generating entities. A cost-containment mechanism is included: the credit price is capped at $200, to be adjusted for inflation going forward. In this section, a review of early attempts at analysis is followed by a summary of measurement techniques after implementation.

The California LCFS was legally adopted in 2009, amended in 2011 (the real time of implementation), and renewed in 2015. It is designed to work in complementarity with other regional emissions reduction programs and target the transport sector specifically. It functions as a standard LCFS, with deficits generated by gasoline and diesel production offset with credits generated from alternative fuel production. The gasoline and diesel credit markets operate separately, in order to prevent a shift from one fossil fuel to the other. Since the program's amended implementation in 2011, alternative fuels have risen from 6.2% of energy content in the transport sector to 8.5% in 2017. From 2011 to 2015 the LCFS required a reduction of 9.2 million metric tons of CO_2e emissions below 2010 levels, and fuel suppliers responded with a reduction of 16.8 million metric tons, exceeding the regulatory requirement by 81% or 7.4 million metric tons. Up until 2017, fuel suppliers exceeded the requirement in aggregate and in every individual quarter.[21] In 2017, deficits exceeded credits for the first time, causing the bank to begin to decline, and the first two quarters of 2018 show the same pattern. As in British Columbia, it is possible that at this point the policy is beginning to more significantly impact decisions by regulated parties (see pg 27 for a further discussion of what this shift might indicate in Oregon). The credit price has been rising steadily (aside from a slight dip in the early months of 2018) over 2017Q2-2018Q1, from around $80 up to a high of $169.

The fuel compliance mix shows the evolution of the alternative fuel market—ethanol fell 40%, from 78% to 38% of total credits generated over the 2011-2015 period, and biodiesel energy use in the transport sector increased by a factor of ten, most likely due to the incorporation of lower-intensity feedstocks (and possibly lingering price effects on corn-based products due to the 2012 drought). In 2015, diesel credits outstripped gasoline credits for the first time since the program's inception. Both of these changes have continued to manifest: ethanol's share of generated credits continues to fall, and diesel remains the largest source of credits. Most increases in alternative fuel use came from changes in the diesel pool, where fuel volume composed of renewable diesel or biodiesel rose from less than half a percent in 2011 to 15.6% in 2018Q1.

Of course, the metric of primary interest is the carbon intensity of transport fuels over the program's span. Over the 2011-2017 period, the average carbon intensity of alternative fuels fell by 21%, from 86 gCO_2e/MJ to 55 gCO_2e/MJ. Reductions in the diesel pool were largest, due to the revised production approach mentioned above (namely, the shift to lower-intensity feedstocks). As of 2018Q2, the CARB

[21] Witcover, Julie. (September 2018.) Status review of California's low-carbon fuel standard, 2011-2018Q1. UC Davis: Institute of Transportation Studies.

listed 494 registered fuel pathways (with associated carbon intensities) and 204 regulated parties on their website. Under the 2015 re-adoption, pathways are grouped into two categories—one for mature, well-documented pathways, and one for emergent pathways, with the goal of simplifying the process by directing well-understood pathways to a simple, automated calculator.

Given the elastic supply-and-demand relationship of credit pricing, the market is highly dynamic, and prices have ranged from $20-25 (when the policy was under legal review due to multiple lawsuits challenging its constitutionality) to as high as $169 per credit in July of 2018, as suppliers face another compliance level adjustment. (Note that prices are determined bilaterally by the trading parties and are thus not constant across the market at a given point in time.) Altogether, credit sales have totaled approximately $430 million since 2011. Over time, the number of entities producing (or producing and purchasing) credits has increased twofold, while the number purchasing exclusively has remained constant. At the time of writing, there are several proposed amendments to the program, including a reduction in CI stringency that would result in a reduction of 7.5% below 2010 levels (instead of the originally proposed goal of 10%), and increases in program scope allowing for more types of opt-ins (including some types of aviation and oceangoing alternative energy use).

Clean Fuels Program: Baseline and Tracking

The following section examines some baseline data relevant to the Oregon Clean Fuels Program, followed by presentation and discussion of a set of trackable indicator variables that relate to economic impacts of the CFP. The baseline section examines the number and type of regulated parties previously and currently registered under the program, and new and existing alternative fueling infrastructure (including electric vehicle charging stations). Tracked indicators include data on the Oregon vehicle fleet, pricing and consumption for certain fuels, and environmental variables (greenhouse gas emissions and Air Quality Index [AQI] values). See Table 2 on p. 5 for an organizational chart of the variables, including their relevance to the Clean Fuels Program.

Industry Baseline

This section establishes program participation and existing alternative fuel infrastructure by presenting dynamic and spatial data on parties registered for the CFP (showing level of program participation by traditional and alternative fuel companies), alternative fuel stations (indicating capital investments related to alternative fuel provision), and electric vehicle charging stations (indicating capital investments related to electric vehicle use).

Registered Parties

At the time of writing, there are 154 parties registered in the credit market program, up from 142 in the final quarter of 2017. Figure 2 provides registered parties by registration classification in the last quarter of 2017 and second quarter of 2018: "Blendstock" denotes sellers of blendstock and finished fuels, while "Large/Small Finished Fuels" denotes importers of finished fuels only (large and small meaning greater or less than 500,000 gallons per year). The drop in the Small Finished Fuels category is illusory; one party formerly registered as such switched categories to Large Finished fuels, and the other switched to Blendstock.

Refueling Infrastructure

There are currently 87 alternative fuel stations in Oregon. Prior to the program's implementation in 2016Q1, there were approximately 23 such stations (not all stations have a reported open date). In 2016, approximately 34 alternative fueling stations were added to the supply, with another 15 reported in 2017 and four in 2018. The composition of these stations, grouped by types of alternative fuel provided, are shown in Figure 3. Three of the 87 fuel stations provide both biodiesel and E85 (85% ethanol blend) fuel, and are not included in the chart. Figure 4 is a map of these station as of November 2018.

While most owners of electric vehicles (also known as EVs) charge them at their residence, there has nonetheless been a proliferation of public EV charging stations, also known as EVSEs (Electric Vehicle Supply Equipment), in recent years. These stations consist of a space for the vehicle and outlet for the cordset issued with all EVs and PHEVs (plug-in hybrid electric vehicles). Considered on an annual basis, the total number of EVs (including PHEVs) in the state correlates almost perfectly with the number of EV charging stations ($\rho = 0.992$). Figure 5 shows the number of new and existing public EV charging stations in the state over the past decade, accompanied by a map of said stations in November 2018. The light green portion at the top of each bar represents new stations added, while each bar in its entirety is the total number of public EV charging stations in the state. Note the acceleration of the trend over the past five years: prior to 2014, an average of eight new stations opened per year, and after that 2014, the average annual openings are closer to 34.

Figure 2: Registered Parties by Registration Classification, 2017Q4 and 2018Q2

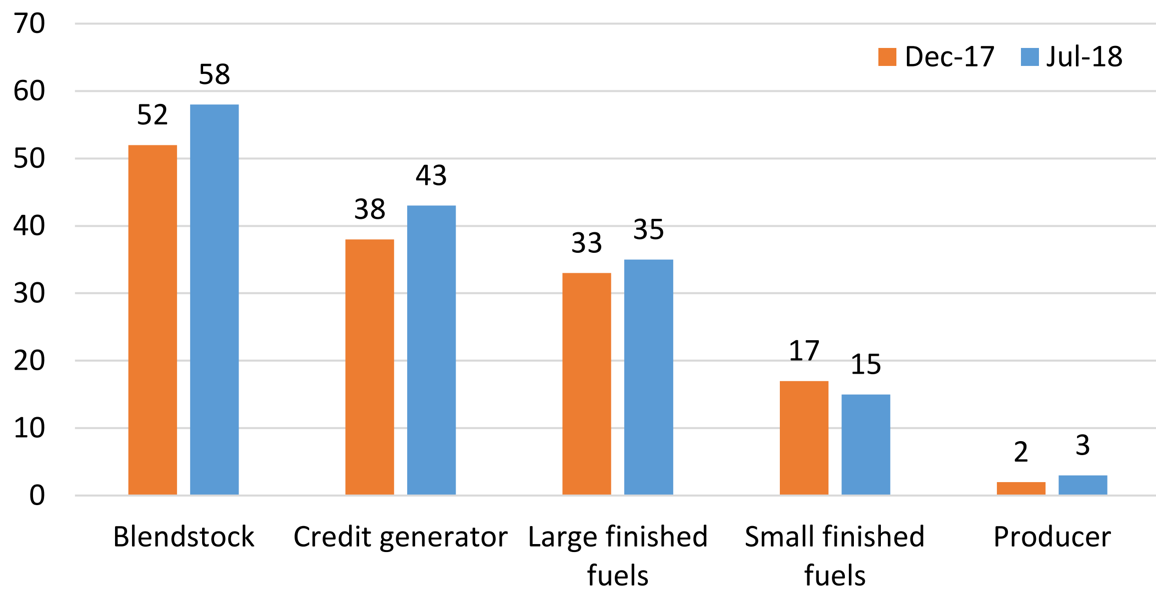
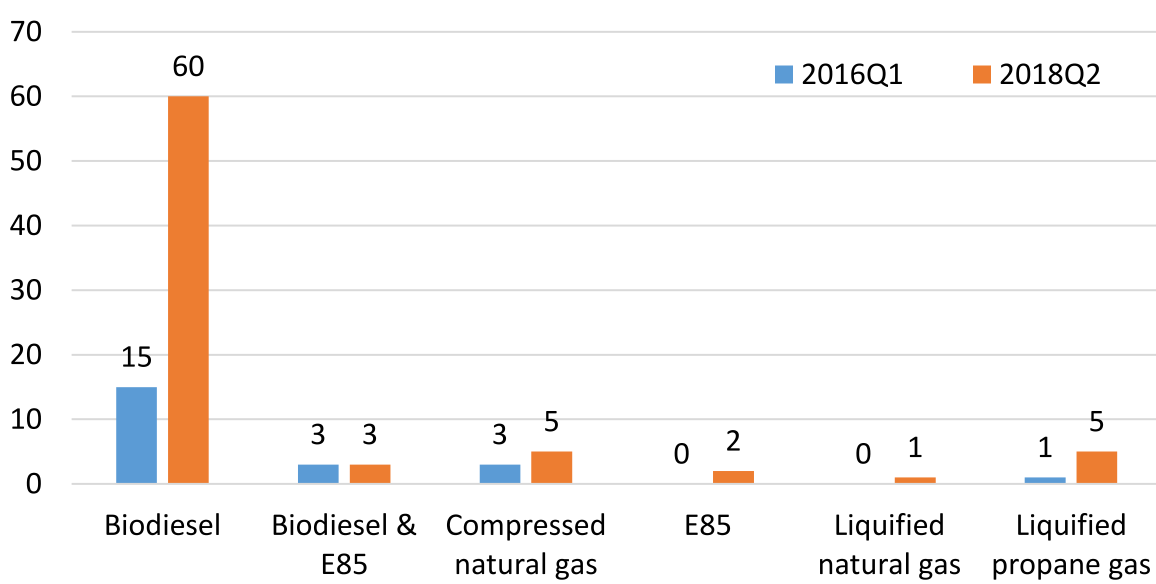


Figure 3: Alternative Fuel Stations by Fuel Type as of November 2018[22]



[22] Energy Efficiency & Renewable Energy, U.S. Department of Energy. Data downloaded from Alternative Fueling Station Locator, Alternative Fuels Data Center. Retrieved from AFDC.Energy.gov.

Figure 4: Map of Alternative Fuel Stations in 2018Q2 (includes stations without recorded open dates)[23]

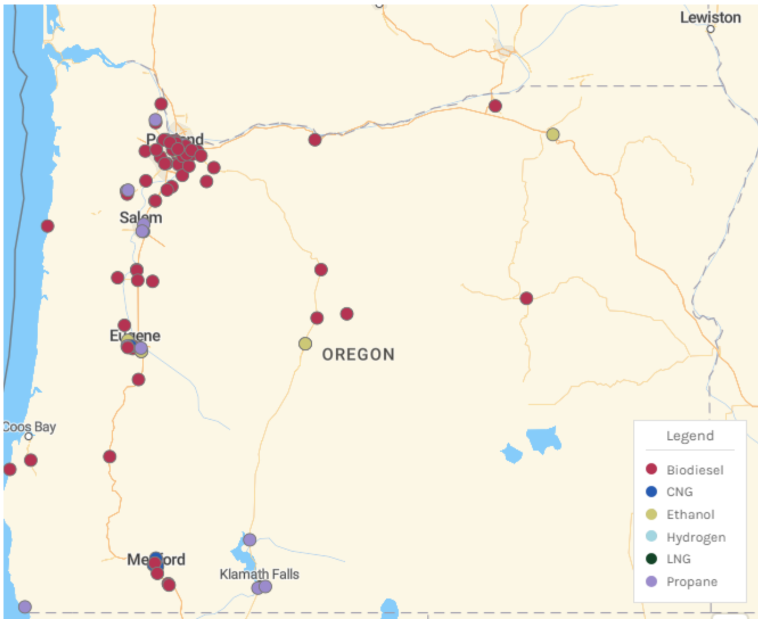
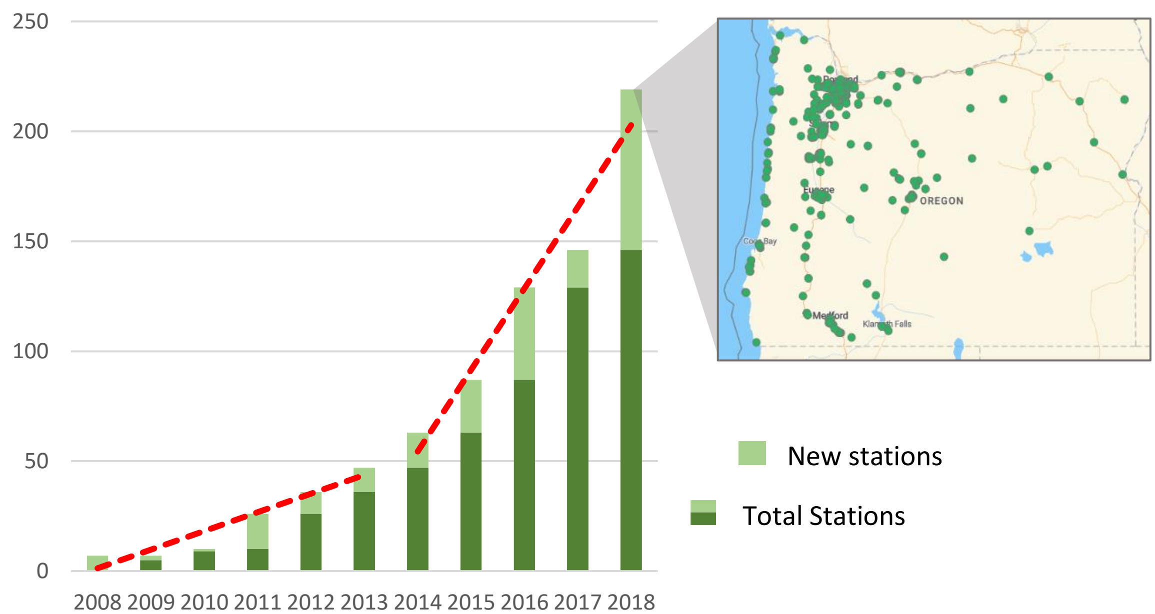


Figure 5: EV Charging Stations in Oregon, 2008-2018[24,25]



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[23] Energy Efficiency & Renewable Energy, U.S. Department of Energy. Map image from Alternative Fueling Station Locator, Alternative Fuels Data Center. Retrieved from AFDC.Energy.gov.

[24] Energy Efficiency & Renewable Energy, U.S. Department of Energy. Data downloaded from Alternative Fueling Station Locator, Alternative Fuels Data Center. Retrieved from AFDC.Energy.gov.

[25] Energy Efficiency & Renewable Energy, U.S. Department of Energy. Map image from Alternative Fueling Station Locator, Alternative Fuels Data Center. Retrieved from AFDC.Energy.gov.

Tracked Indicators

The following pages present data that will be used to assess the economic impact of the CFP going forward, and include values and growth rates for components of the Oregon vehicle fleet, consumption and pricing of various traditional and alternative fuels, and environmental indicators (greenhouse gas emissions and Air Quality Index [AQI] values).

Vehicle Fleet

Since 2009, the total number of vehicles in Oregon has grown by an average of 1.3% per year, roughly matching the population growth rate as expected. As of June 2018, the total number of vehicles registered in Oregon is 3.72 million, including 45,655 government vehicles. The fleet is made up of approximately 45.4% cars, 25% SUVs, 6.2% vans and 23.3% trucks~~ as of June 2018~~. The average age of vehicles in the fleet is 12.7 years, and~~but~~ has fluctuated between 12 to 13 years over the past decade. Each year, approximately 556,000 vehicles are newly registered in the state and 511,000 exit from the list (at an average age of 15.27 years). Figure 6 shows the vehicle fleet by type and year; note that while cars still dominate the market, SUVs are growing more rapidly than any other category of vehicle. Figure 7 provides the year-over-year growth rates for the four main vehicle types.

The vehicle fleet average fuel efficiency (miles per gallon – MPG) of the Oregon fleet has grown from 19.8 MPG in 2009 to the current level of 21.8 MPG, increasing by a rate of 1.1% annually. This annual growth rate has increased slightly to 1.2% since the implementation of CFP in 2015. Figure 8, below, is a map that shows average miles per gallon by zip code before and after program implementation. The average MPG of vehicles within a given zip code is typically higher in less rural areas, and is rising over time in both urban and rural zip codes.

Figures 9 and 10, below, show the number of EVs registered in each zip code in 2018, and the number of EVs added to each zip codes' vehicle registrations between 2015 and 2018. As would be expected, most EVs are registered in urban areas, and most EV growth is occurring in urban areas as well.

Returning to Figure 6, the number of EVs (including PHEVs) is shown with a green line (associated scale is represented on the secondary axis). While EVs still make up a very small percentage of the fleet—half of one percent in June of 2018—they are growing rapidly. Figure 11 shows the total stock of EVs and PHEVs on a monthly basis. While it is difficult to show growth in a meaningful way when quantities change dramatically (for example, an increase from 1 to 2 would manifest as a 100% growth rate), it is worth noting that the number of EVs in Oregon increased by nearly 2,800% from January 2011 to May 2018; this is a very strong rate of growth in comparison to that for the entire vehicle stock (13%) or even the more-rapidly growing SUV vehicle type (36%). On average, the stock of EVs increased annually by 93% (compared to 1.26% for all vehicles) over that time period. While the significant growth of EVs in the Oregon fleet cannot be definitively attributed to the CFP, the increasing capital investment into EV charging stations across the state can be seen as evidence of growing commitment to alternative fueling infrastructure that support alternative fuel vehicles in the fleet.

Figure 6: Oregon Vehicle Fleet by Type and Total EVs Registered in State, 2009-2017

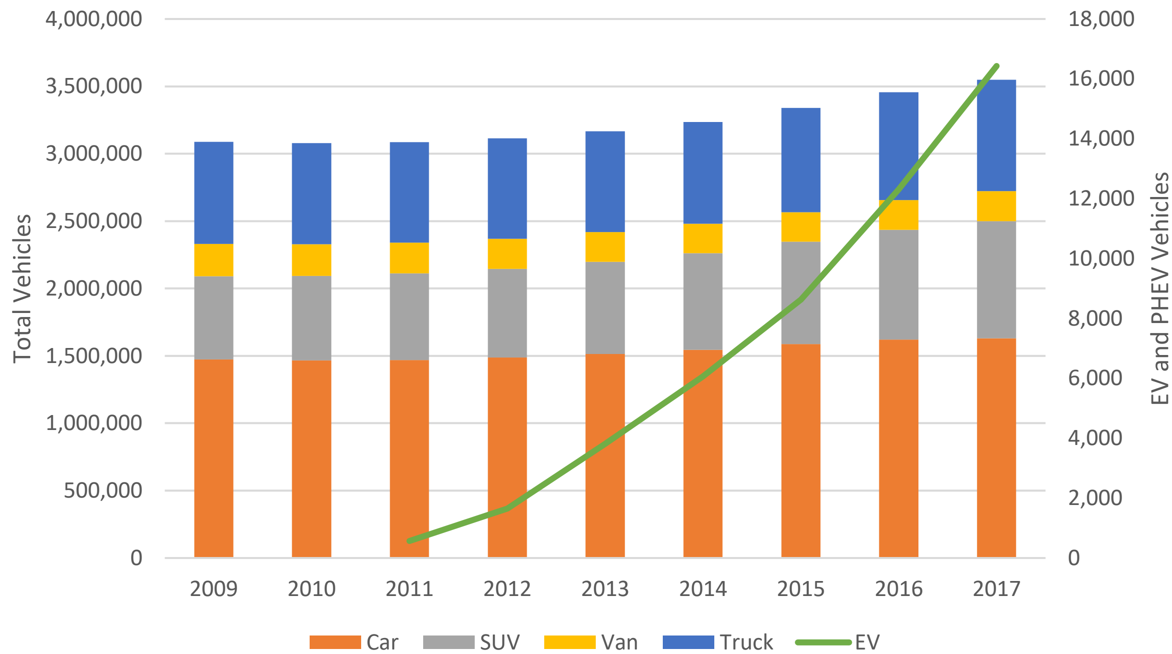


Figure 7: Oregon YoY Growth Rates by Vehicle Type, 2010-2017

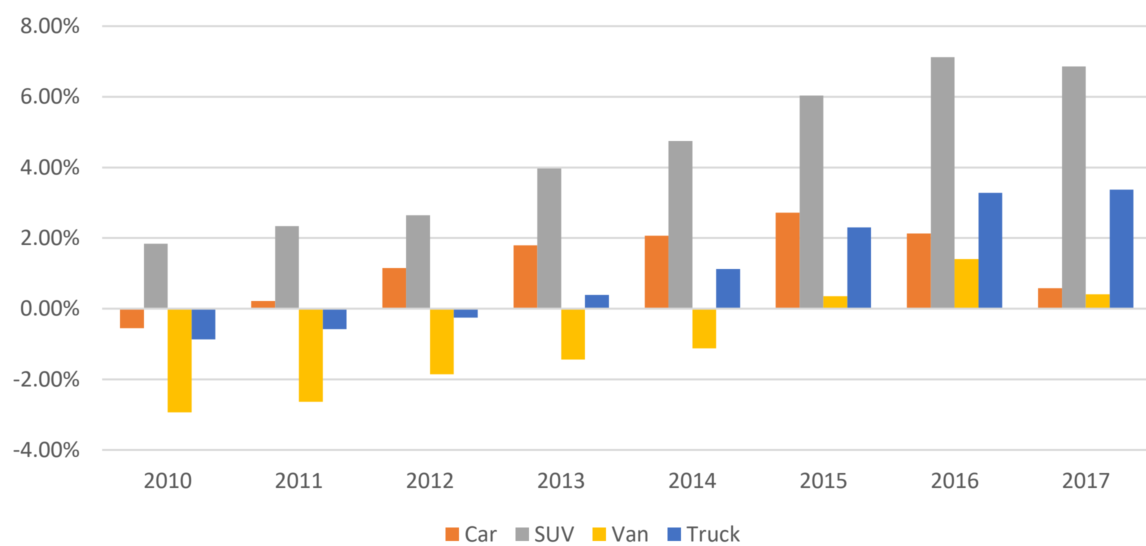


Figure 8: Average MPG by Zip Code in 2015 and 2018

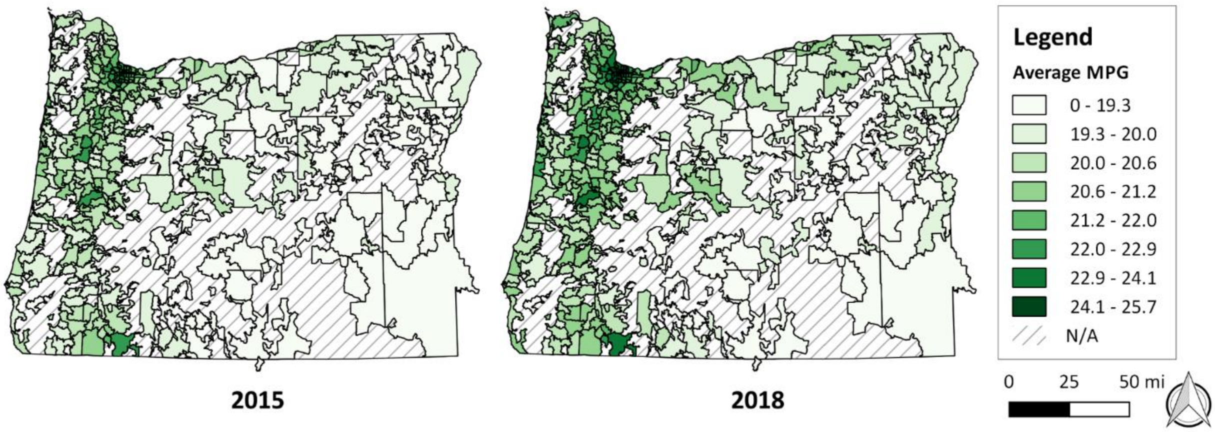


Figure 9: Number of EVs (including PHEVs) by Zip Code in 2018

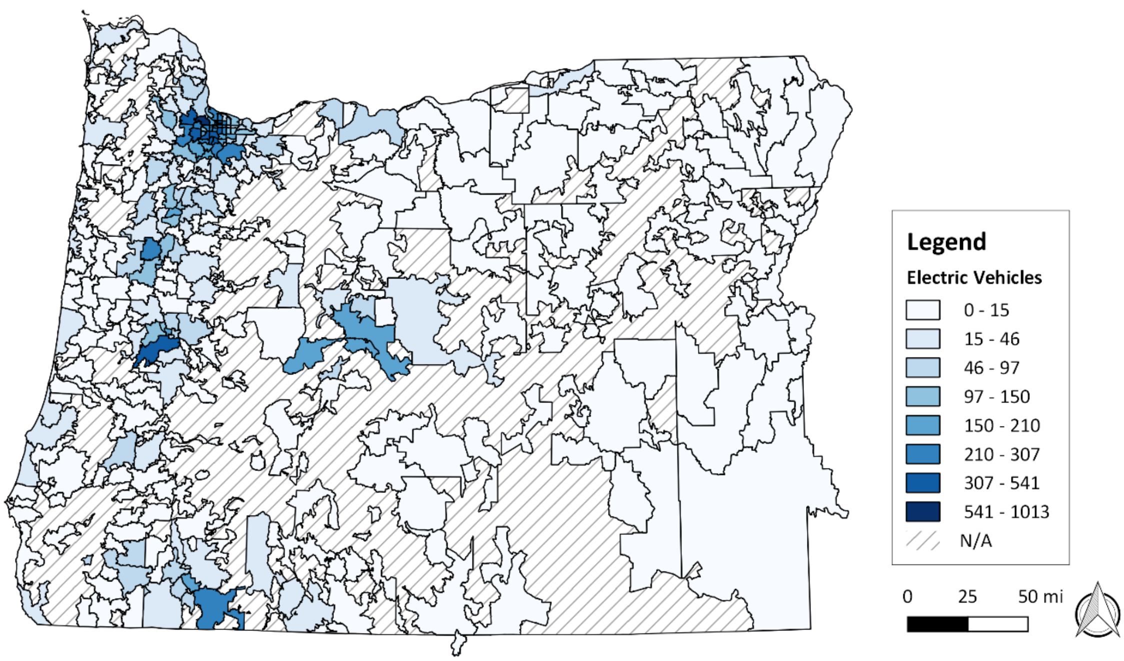


Figure 10: Number of EVs Added between 2015 and 2018, by Zip Code

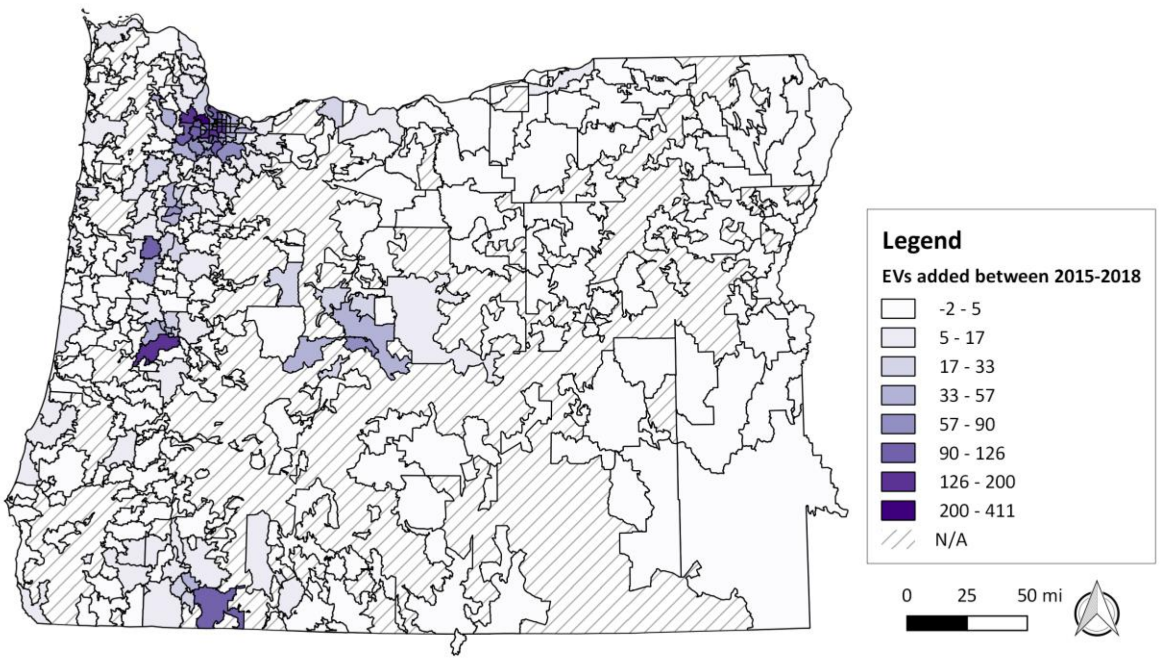
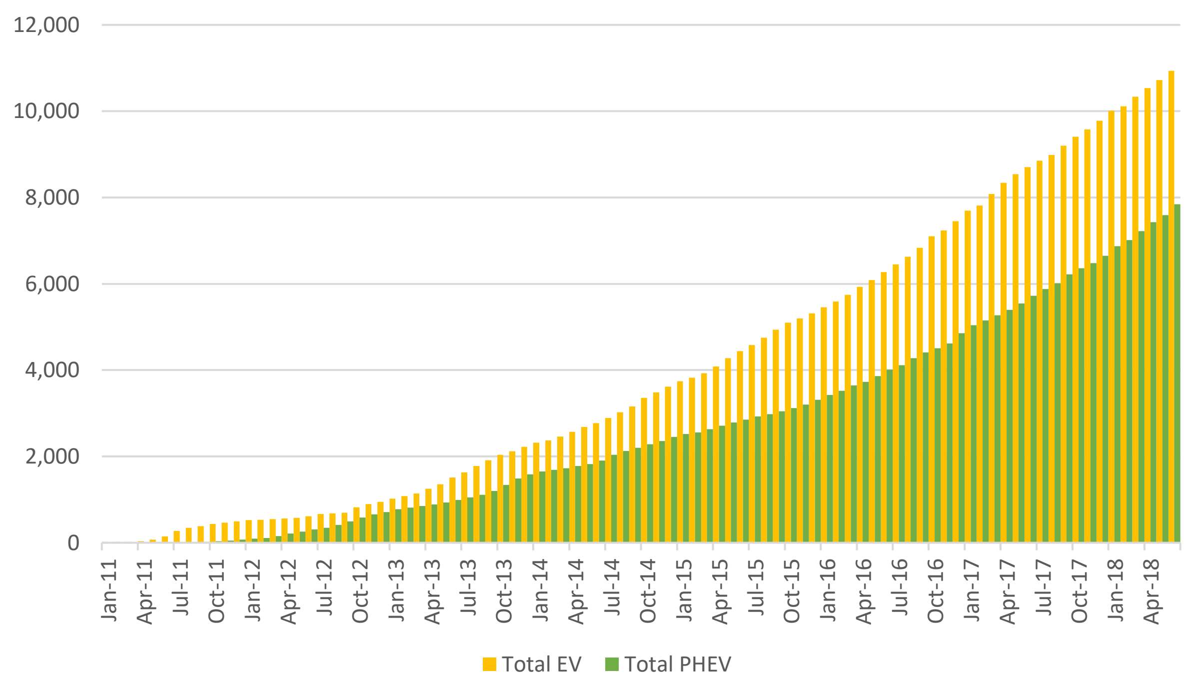


Figure 11: Total Stock of Electric Vehicles and Plug-In Hybrid Vehicles in Oregon, Jan 2011-May 2018



Fuels

Fuel Consumption

Total fuel consumption as recorded by DEQ is shown in Figure 12. In every quarter since implementation, ethanol and biodiesel blends, along with all other alternative fuels recorded, constitute between 11% and 13% of total consumption. While a cyclical, seasonal trend in fuel consumption is apparent, the authors have not been able to discern any apparent trend in the consumption of these fuels following the implementation of CFP at time of writing. However, because short run price elasticities of demand for fuels tend to be smaller than long run elasticities, fuel consumption trends may become more evident in future iterations of this report.

Fuel Pricing

The following data are derived from the US Energy Information Administration (Figure 13) and the Clean Cities Alternative Fuel Price Report (Figures 14, 15), which is produced by the US Department of Energy's Energy Efficiency and Renewable Energy Division. The latter is a recurring quarterly report that aggregates submitted prices from thousands of alternative fuel providers; the 2018Q2 report presents results derived from 4,283 submissions. At time of writing, the 2018Q3 report is due for release and the results are included in the graphs below. While the data in Figures 14 and 15 is national in scope, the gasoline price on the West Coast (minus California) shown in Figure 13 tracks closely with the national average, indicating that values are comparable, with the West Coast falling $0.22 above the nation as a whole (averaged across the depicted quarters). The well-documented 2014-2016 drop in the price of oil, due to synchronous growth slowdowns in several emerging markets in combination with a technology-driven increase in supply, is evident in the pricing for gasoline (including the E85 ethanol blend) and diesel (including biodiesel blends).[26] There does not appear to be much discernable effect of the CFP at this time; the price of gas on the West Coast (less CA) follows the movements of the national price. It is worth noting that following the implementation of the CFP in 2016Q1, the difference between the West Coast (minus California) and national gas prices has increased, from an average of $0.16 to an average of $0.33; however this cannot necessarily be attributed to the increased cost imposed by the CFP and the local gas price still tracks with the national level, albeit at a slightly higher rate.

Figures 14 and 15 show the national prices of various alternative fuels in comparison to the national prices of gasoline and diesel respectively. There is not much to assess in these price graphs, which reflect the nature of the wider market rather than local impacts of the CFP and are included in this report in large part as factors that might influence the outcomes of the CFP rather than variables affected by the CFP. Fuels derived from natural gas (such as propane and compressed or liquefied natural gas) have remained relatively stable in price, while gasoline and diesel blends reflect the trends in Figure 13.

[26] Rogoff, Kenneth. (March 2 2016). What's behind the drop in oil prices? World Economic Forum. Retrieved from weforum.org.

Figure 12: Total consumption by Fuel Type, 2016Q1-2018Q2

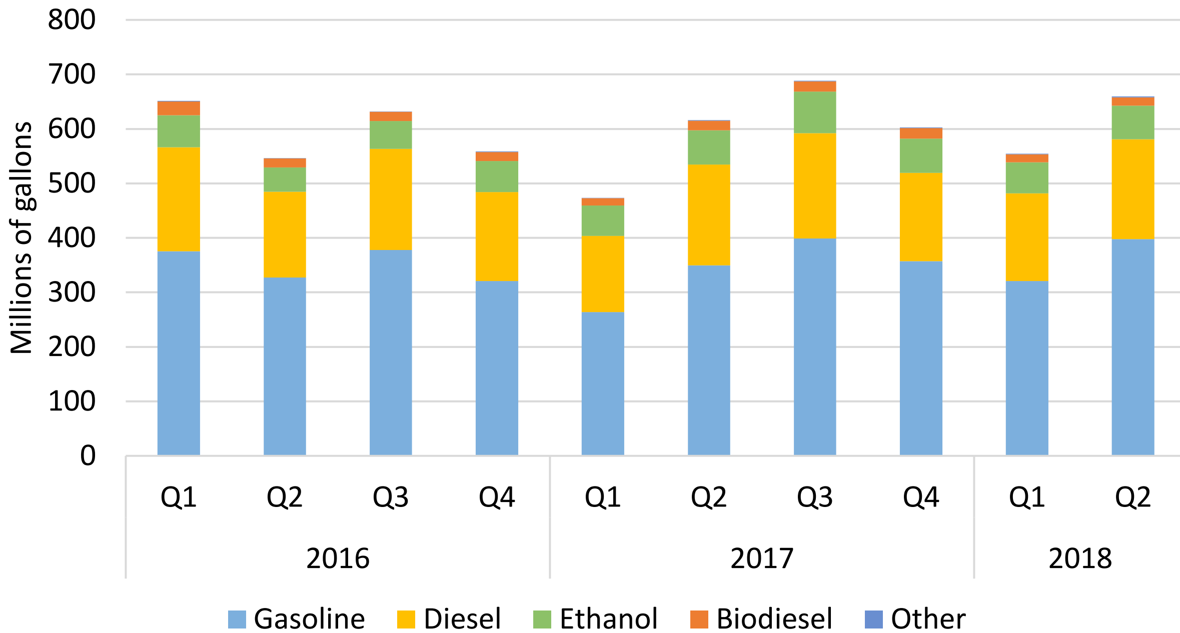


Figure 13: Gasoline Price in US vs West Coast (minus California), 2010Q2-2018Q4

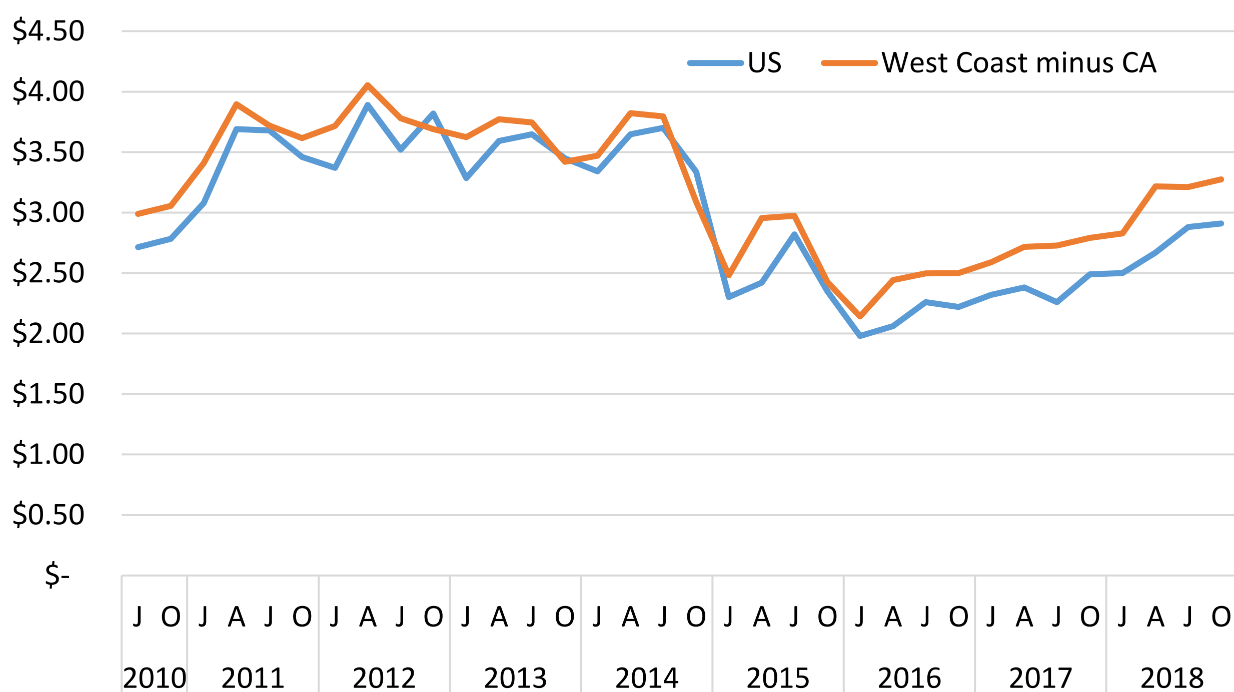


Figure 14: Various Alternative Fuel Prices vs Gas Price, US, 2010Q2-2018Q4

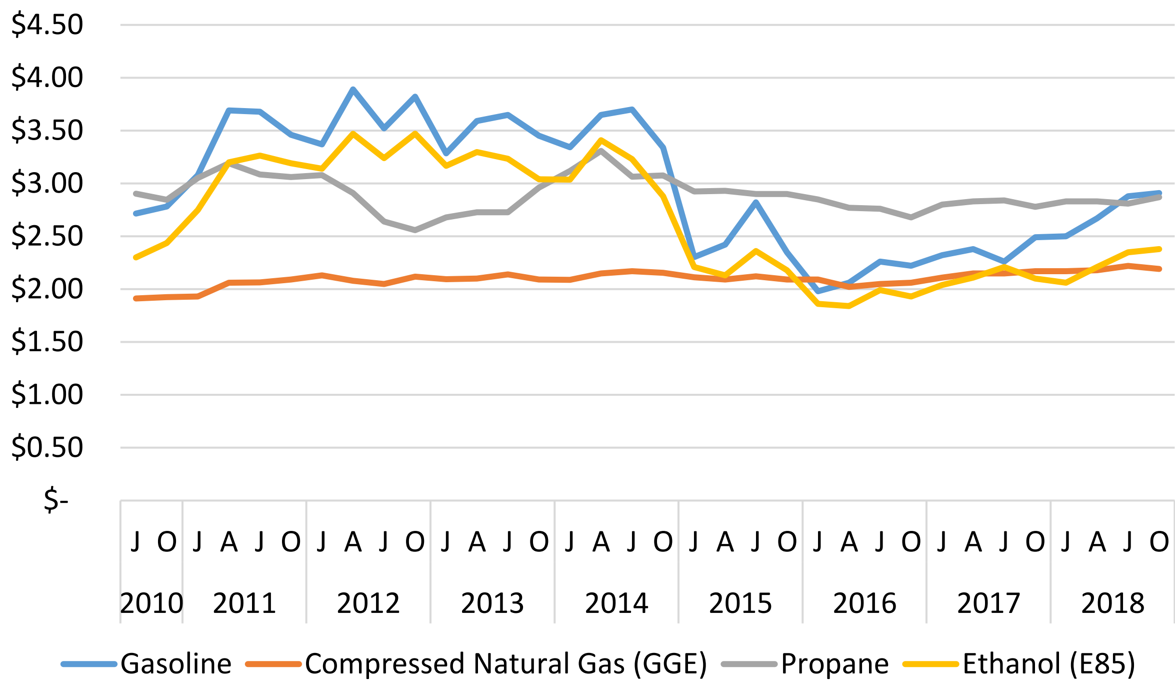
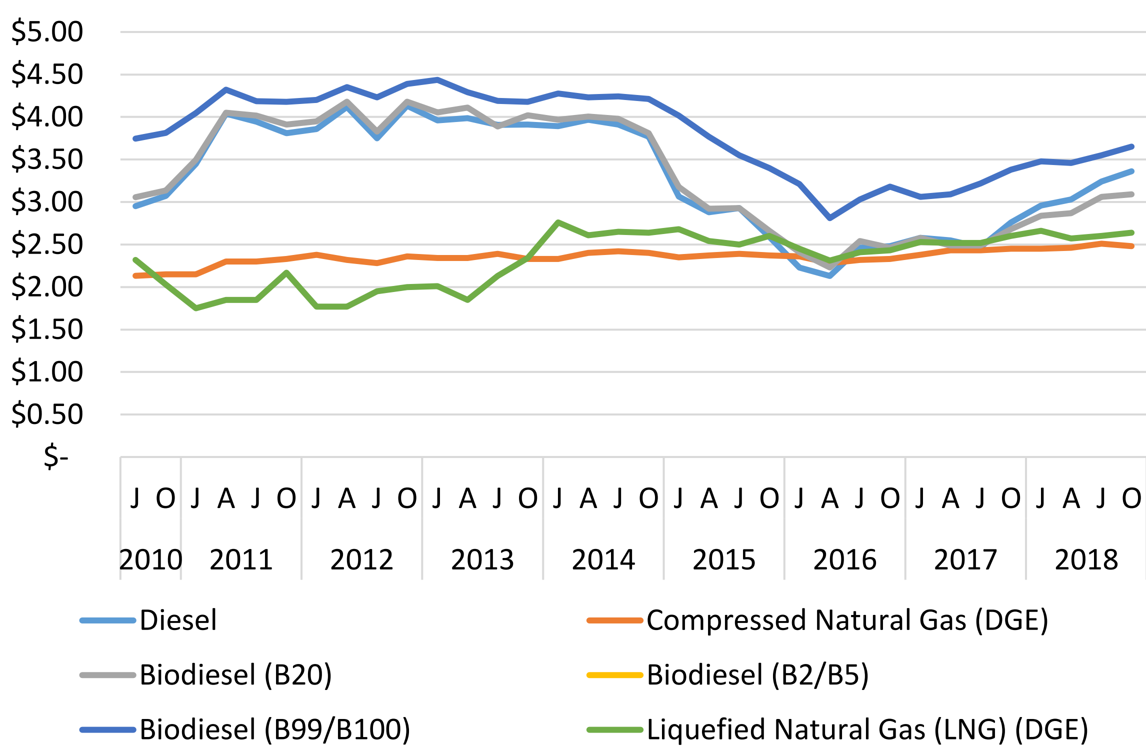


Figure 15: Various Fuel Prices vs. Diesel Price, US, 2010Q2-2018Q4

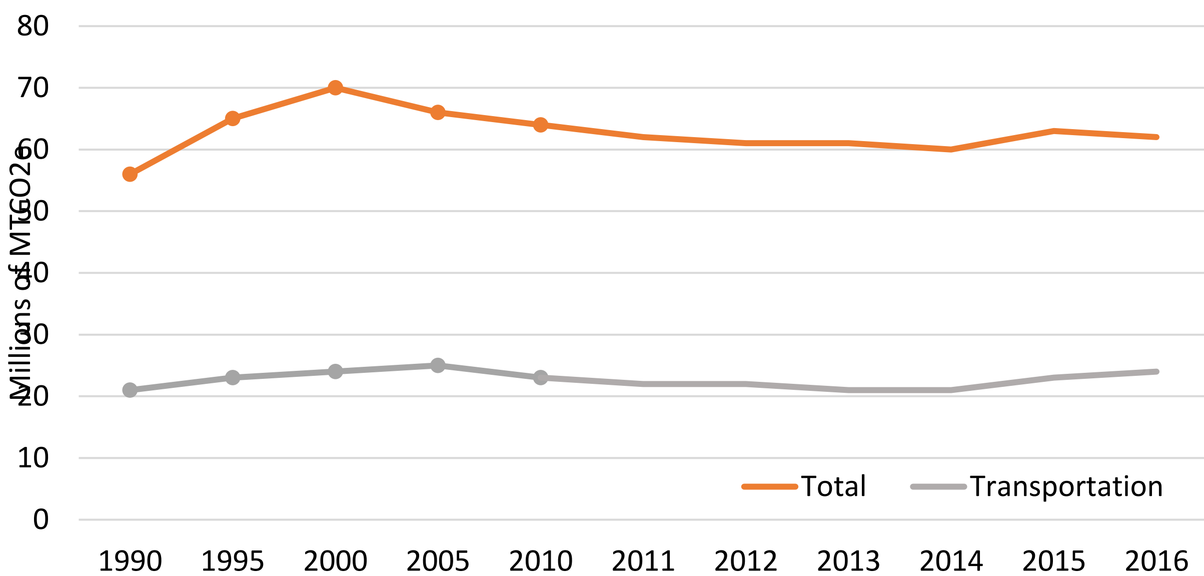


Environmental Indicators

GHG Emissions

Total greenhouse gas emissions in Oregon (presented in metric tons of carbon dioxide equivalent, or MTCO2e), fell starting in 2000. Transportation emissions fell as well, albeit to a lesser degree—transportation is known to be a fairly inelastic sector (as mentioned in the Background section of this report, p. 6). Emissions declined gradually from 2011 on, before beginning to increase in 2015; this is in keeping with general economic activity (i.e., the recent recession and recovery). Unfortunately, at the time of writing the most recent emissions numbers are from 2015 (the 2016 results are preliminary), and therefore it is not yet possible to examine this indicator in the context of the LCFS program. Note that in Figure 16, the marked portion of the series (prior to 2010) denote GHG emissions levels at five-year intervals while the portion without markers show annual GHG emissions in Oregon.

Figure 16: Greenhouse Gas Emissions in Oregon, 1990-2015 with preliminary 2016 estimates



Air Quality

Under the Clean Air Act, the Environmental Protection Agency (EPA) calculates a daily Air Quality Index (AQI) using environmental monitor values five major air pollutants: ground-level ozone, particle matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. The AQI typically ranges between 0 and 500 (with values greater than 500 considered to be beyond the index, or hazardous), and is divided into six levels that relate to potential health concerns (shown in Table 3). Table 4 shows that the majority of counties in Oregon experienced median AQIs in the “Good” range both before and after the implementation of the CFP. However, a comparison of the three-year average median AQI before (from 2013-2015) and after (2016-2018) the program indicates widespread improvements in air quality across the state (except in Wasco County), with Deschutes, Wallowa and Grant Counties showing the most significant decreases in its AQIs.

Table 3: Levels of Health Concern of the Air Quality Index (AQI)[27]

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*...air quality conditions are:*	*...as symbolized by this color:*
0 - 50	Good	Green
51 - 100	Moderate	Yellow
101 - 150	Unhealthy for Sensitive Groups	Orange
151 - 200	Unhealthy	Red
201 - 300	Very Unhealthy	Purple
301 - 500	Hazardous	Maroon

Table 4: Change in Median Air Quality Index (AQI) Before and After CFP Implementation[28]

County	Median Air Quality Index (AQI)		
	2016-2018 Average	2013-2015 Average	Change
Baker County	22.0	26.3	-4.3
Benton County	15.0	16.2	-1.2
Clackamas County	31.3	31.7	-0.3
Columbia County	26.7	27.3	-0.7
Crook County	23.2	27.3	-4.2
Deschutes County	21.0	33.0	-12.0
Douglas County	19.5	23.0	-3.5
Grant County	27.0	35.0	-8.0
Harney County	25.0	29.0	-4.0
Jackson County	39.3	44.0	-4.7
Jefferson County	28.0	29.3	-1.3
Josephine County	26.7	29.3	-2.7
Klamath County	30.0	34.0	-4.0
Lake County	21.3	25.0	-3.7
Lane County	36.3	40.0	-3.7
Linn County	20.0	23.7	-3.7
Marion County	32.0	32.3	-0.3
Multnomah County	32.3	34.3	-2.0
Umatilla County	36.7	37.0	`-0.3
Union County	16.7	29.3	-12.7
Wallowa County	14.2	21.3	-7.2
Wasco County	33.0	21.3	11.7
Washington County	30.7	33.7	-3.0

[27] AirNow. (July 27 2017.) Air Quality Index- A guide to air quality and your health. U.S. Environmental Protection Agency. Retrieved from AirNow.gov.
[28] U.S. Environmental Protection Agency. (2013-2018.) Air Quality Index Report. Retrieved from EPA.gov.

Credit Market

At the time of writing, this program is finishing up its tenth active quarter, and credit market data is available for 2016Q1-2018Q2. See Figure 17 for a summary of credits, deficits, and banked credits by quarter.

Over the period that the program has been active, credits have exceed deficits in every quarter except for the most recent one. It is important to note that credits generated by charging electric vehicles at home are not yet included; they are collected on an annual basis and distributed between quarters in the first report following the year of their issuance (meaning that said credits for 2018 will be included in the 2019Q1 report). Banked credits, which accumulate when credits exceed deficits in a given period, rose steadily for the first two years of the program as entities overcomplied with the new regulation, before decelerating in 2017Q4 and starting to fall in the first half of 2018 (due to the excess of deficits over credits). This change in the market indicates that the regulation may be beginning to "bind"—that is, that the expansion of current clean fuels facilities and infrastructure may be necessary to meet the carbon intensity pathway going forwards. In other words, the lowest-cost mitigation measures have at this point been taken, and compliance will entail a higher price going forward.

An examination of monthly credit transfer data appears to bear out this interpretation. Figure 18 illustrates the number of credits sold in each month over the period since implementation, and the average purchase price per credit. Note the escalation of credit price growth in the second quarter of 2018—said value has nearly doubled over this year, indicating that regulated parties are increasingly willing to pay for credits, rather than change their own practices. The earlier slack in the market attributable to easily-changed practices appears to be dissipating, and increased credit prices are the market manifestation of this change. However, additional data points will be necessary to conclude whether this is indeed a continuing trend or a temporary fluctuation.

Figures 19 and 20 show the composition of generated credits by fuel type over the period since implementation, for all fuel types and for ethanol specifically, by blend type. Over the entire period, most credits have been generated via ethanol blends, with biodiesel coming in second. Fuels falling into the "Other" category comprise 5% or less of total credit generation across all quarters.[29]

Figure 20 shows the distribution of blend types among credits generated by ethanol. The blend number is associated with the volumetric percent ethanol (for example, Ethanol 55 is fuel that is 55% ethanol and 45% conventional gasoline). Blends greater than 75% make up the smallest portion, and blends lower than 55% are the next smallest group. Most credits are generated with ethanol blends of between 55% and 75%.

Figure 21 shows the composition of generated deficits by fuel type. Gasoline makes up the majority of said deficits, with diesel coming in next and finally ethanol, and other fuel types.[30]

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[29] Fuels categorized as "Other" on Figure 19: Bio-CNG/LNG, Diesel (including Imported Finished B5 and B20), On- and Off-road Electricity, Fossil CNG, Gasoline (including Imported Finished E10), Liquefied Petroleum Gas, and Renewable Diesel.

[30] Fuels categorized as "Other" on Figure 21: Bio-CNG/LNG, Biodiesel, Imported Finished B20 and B5 Diesel, On- and Off-road electricity, Imported Finished E10 Gasoline, Liquefied Petroleum Gas, and Renewable Diesel.

Figure 17: Credits, Deficits, and Banked Credits by Quarter, 2016Q1-2018Q2[31]

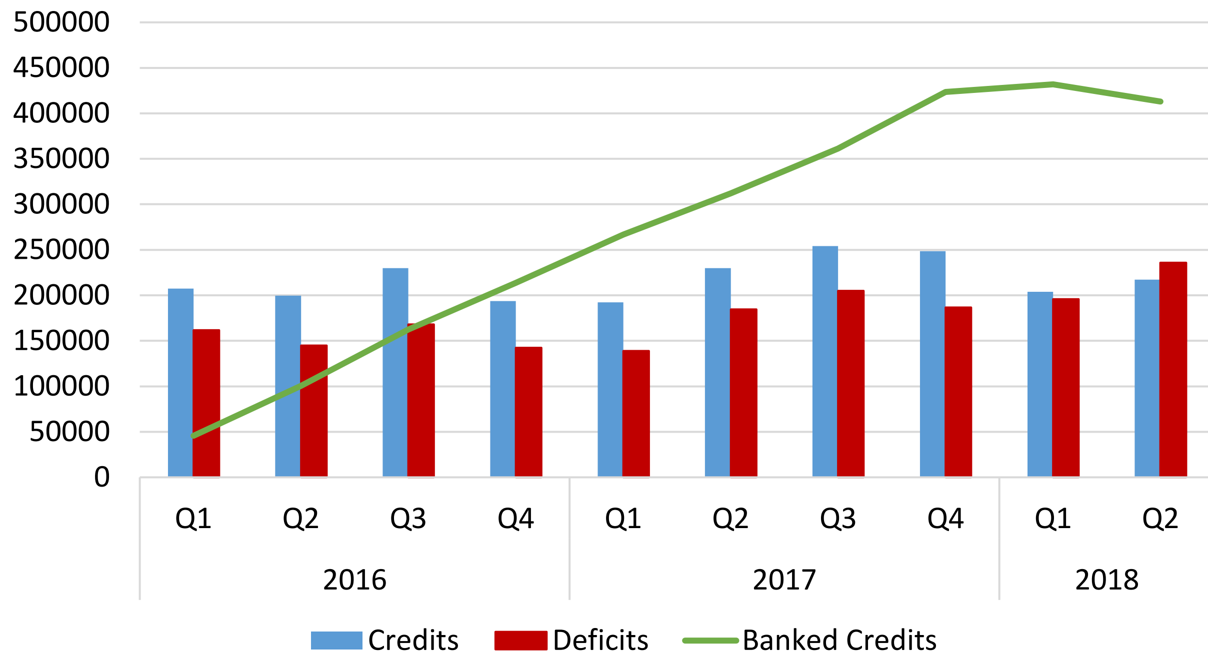


Figure 18: Total Credits Sold and Average Purchase Price, 2016Q1-2018Q2

[31] Clean Fuels Program Second Quarter 2018 Data. (2018.) State of Oregon Department of Environmental Quality. Retrieved from

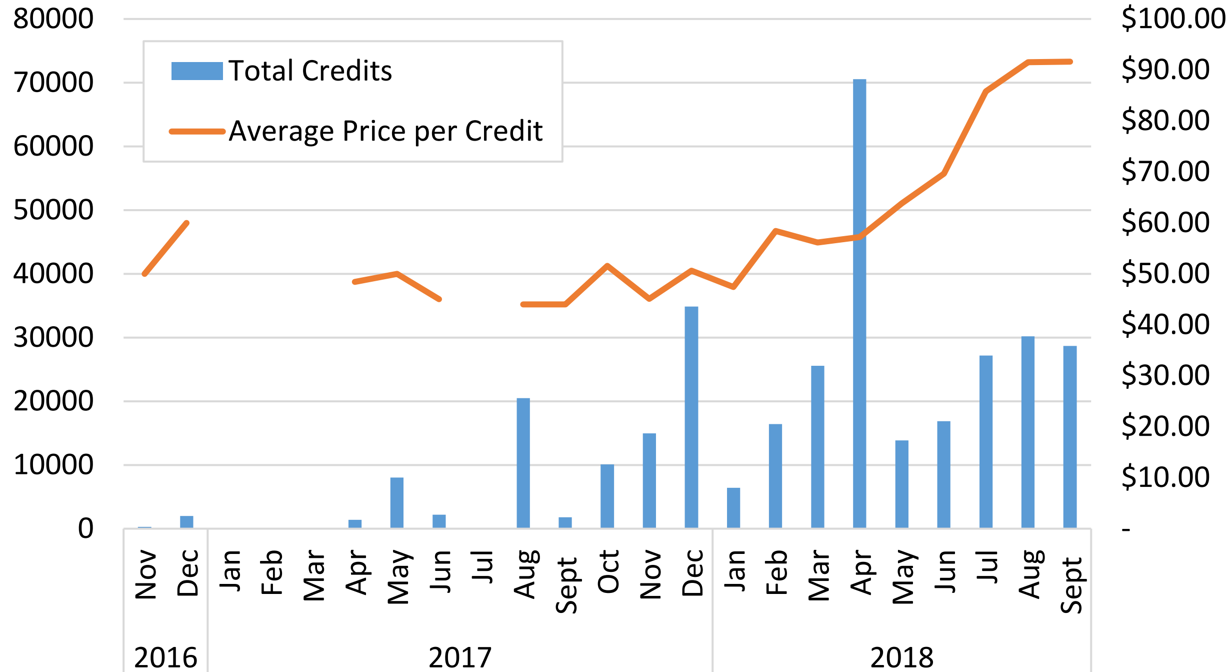
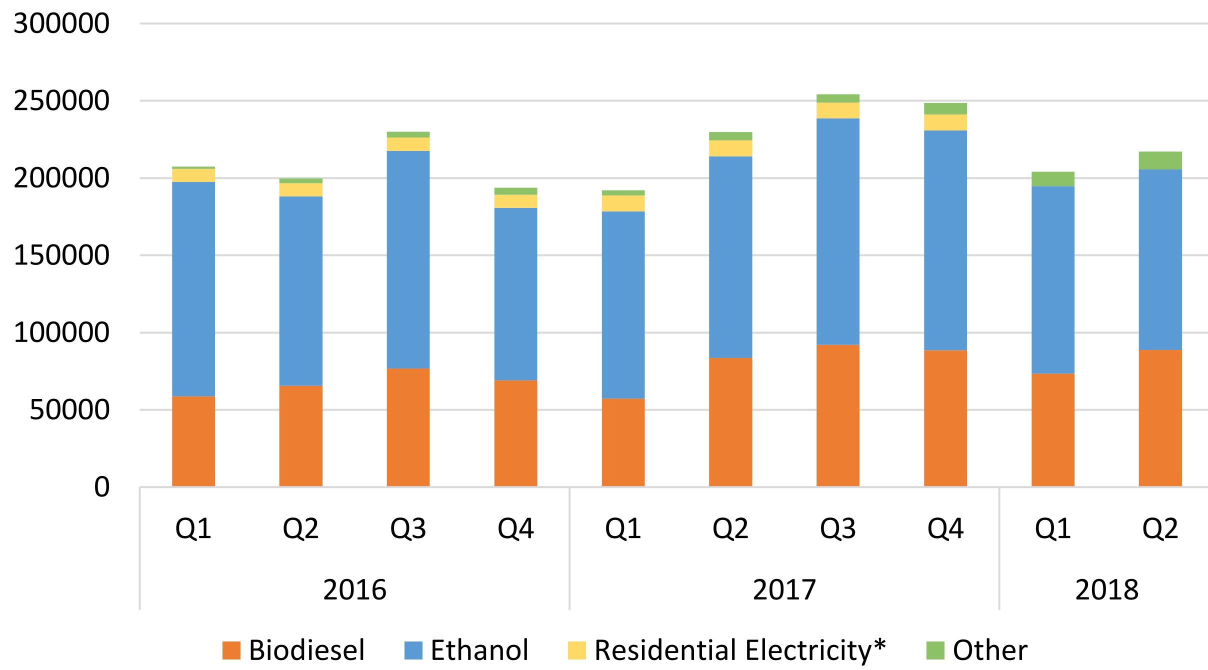


Figure 19: Composition of Generated Credits by Fuel Type, 2016Q1-2018Q2



*Residential electricity credits include credits from utilities, and backstop aggregator credits. They are reported annually and then averaged retroactively across the year in which they were generated.

Figure 20: Composition of Generated Credits, Ethanol Only by Blend Type, 2016Q1-2018Q2

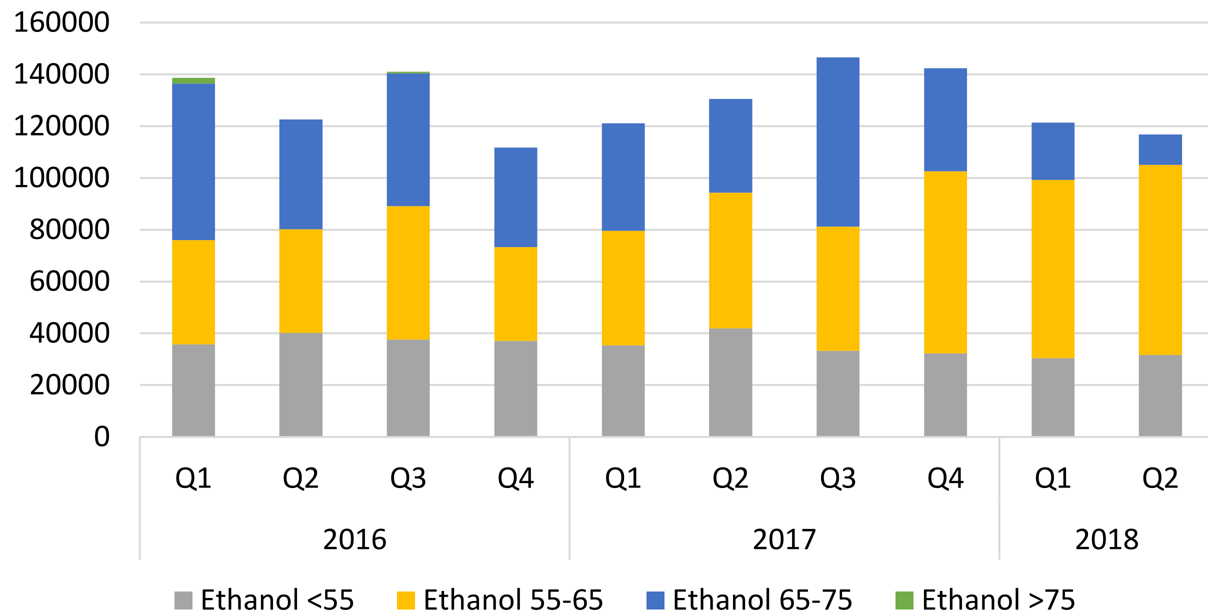
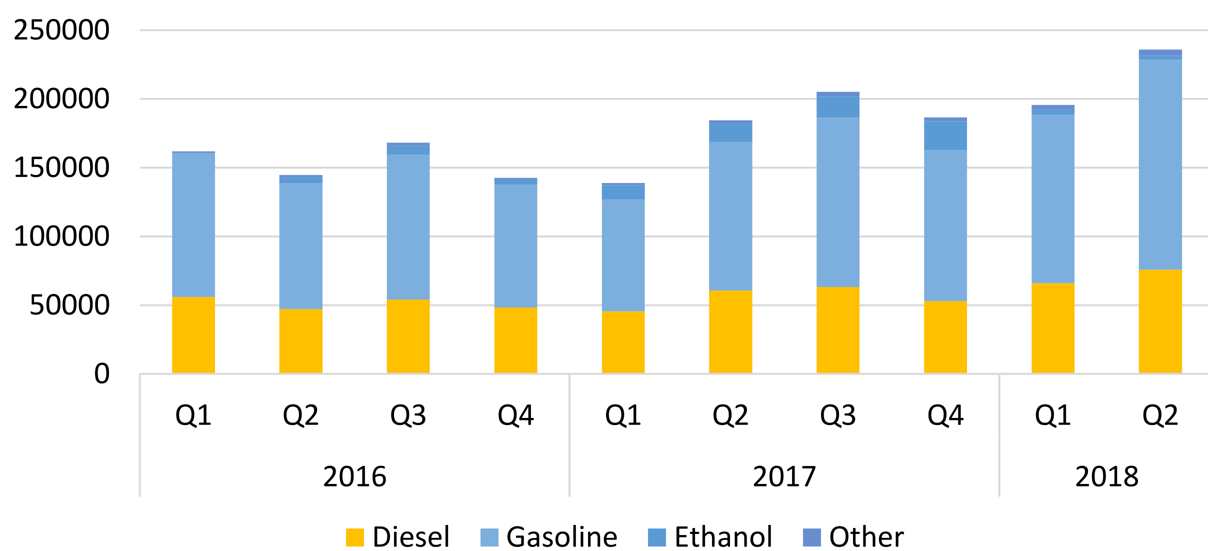


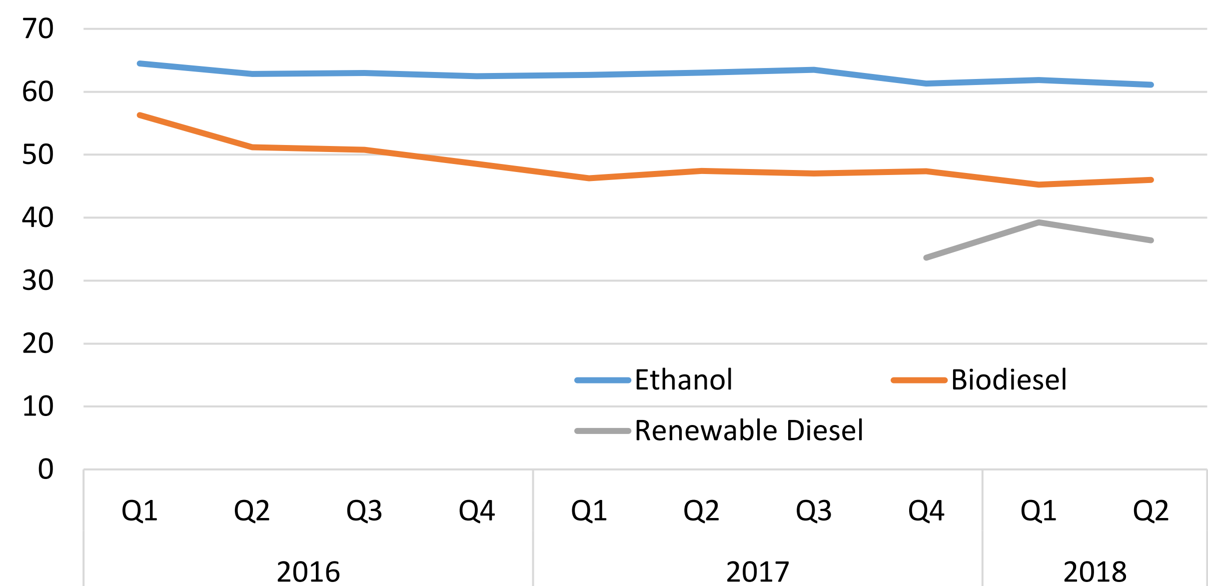
Figure 21: Composition of Generated Deficits by Fuel Type, 2016Q1-2018Q2



The average carbon intensity of fuels covered by the program has fallen slightly over its duration. This value is calculated by averaging the values assigned to the fuel pathways reported by program participants, taking volume into account. As shown in Figure 22, reported values for ethanol blends have declined from an average of 64.5 gCO2e/MJ (grams of carbon dioxide equivalent per megajoule generated) in 2016Q1 to an average of 61.12 in 2018Q2, for an overall decline of 5%. Biodiesel blends have declined more steeply, falling 18% from an average of 56.3 gCO2e/MJ to an average of 46.03

gCO2e/MJ over the same period. This fall is due to different pathway choices by regulated parties—choosing a fuel source with a lower carbon intensity, for example, or even the same fuel from a source that is geographically closer and thus requires less transportation.

Figure 22: Average Carbon Intensity of Select Fuels, 2016Q1-2018Q2



Conclusion

Oregon's Clean Fuels Program is designed to incentivize the use of alternative energy for transportation within the state. In order to accomplish this, the state has established a schedule of carbon intensity requirements that fuel suppliers must meet by either modifying their supply chain or purchasing credits on an open market. These credits, which are produced by entities that generate alternative energy, have historically exceeded deficits generated by traditional fuel production (or any production not meeting the applicable carbon intensity level), but as of the second quarter of 2018, this is no longer the case. This indicates that the program may be starting to have its intended effect: regulated parties may have used up the lowest-cost measures available to them at this time, and future mitigation will require adjustments with a more significant impact. Ideally, these approaches will include innovative strategies for production and transport, as the goal of programs like this one is to both curb current carbon emissions and spur technological development.

The number of parties regulated by the CFP currently sits at 154, with the majority registered as blendstock sellers or large and small importers of finished fuels. While no clear trend in fuel consumption (both conventional and alternative) or fuel pricing has been discernible following the implementation of the Oregon CFP, there has been evidence of increasing capital investments into alternative fueling infrastructure, including both electric vehicle charging stations (growing from 87 to 219 between 2016 and 2018) and alternative fuel stations (growing from 23 to 87). The Oregon vehicle fleet has increased by an average of 2.81% per year (about double the annual average rate since 2010) during this same period, but the most significant growth appears in the electric vehicle category (38.8% average annual growth). While the significant growth of EVs in the Oregon fleet cannot be definitively attributed to the CFP, the increasing capital investment into EV charging stations across the state can be seen as evidence of growing commitment to alternative fueling infrastructure. We expect most indicators to more fully manifest program impacts as time goes on, as additional data for GHG emissions and air quality for the CFP implementation become available.

As the first in a series, this report establishes a baseline for infrastructure and program participation, and selects a set of economic indicators that encompass potential program impacts and influences for program tracking and evaluation. Going forward, these indicators will be collected and presented as they become available, providing a dynamic assessment of the CFP's impact within the state.

References

AirNow. (July 27 2017.) Air Quality Index- A guide to air quality and your health. U.S. Environmental Protection Agency. Retrieved from AirNow.gov.

Clean Fuels Program Second Quarter 2018 Data. (2018.) State of Oregon Department of Environmental Quality. Retrieved from Oregon.gov/DEQ.

Energy Efficiency & Renewable Energy, U.S. Department of Energy. Data downloaded from Alternative Fueling Station Locator, Alternative Fuels Data Center. Retrieved from AFDC.Energy.gov.

Energy Efficiency & Renewable Energy, U.S. Department of Energy. Map image from Alternative Fueling Station Locator, Alternative Fuels Data Center. Retrieved from AFDC.Energy.gov.

Farrell, A. E, & Sperling, D. (2007a, 2007b). A Low-Carbon Fuel Standard for California, Part 1: Technical Analysis and Part 2: Policy Analysis. UC Davis: Institute of Transportation Studies (UCD). Retrieved from escholarship.org

FORTH. (September 11, 2018). Clean Fuels Backstop Aggregator Workplan. Retrieved from Oregon.gov/DEQ

Fuels Quality Directive (FQD). (2017.) Retrieved from FuelsEurope.eu.

Gas prices tend to have little effect on demand for car travel. (December 15, 2014). Retrieved from EIA.gov.

Holland, S. (2012). Taxes and Trading versus Intensity Standards: Second-Best Environmental Policies with Incomplete Regulation (Leakage) or Market Power. Journal of Environmental Economics and Management 63(3), pp. 375–387.

Hill, J., L. Tajibaeva and S. Polasky. (2016.) Climate consequences of low-carbon fuels: the United States Renewable Fuel Standard. Energy Policy, 97, pp. 351-353

Lade, G.E and C.-Y.C. Lin. (2015.) The design and economics of low carbon fuel standards. Research in Transportation Economics, 52, pp. 91-99

Low Carbon Fuel Credit Market Report. (October 2018.) Retrieved from www2.gov.bc.ca.

Oregon Department of Environmental Quality. Clean fuel standards. Retrieved from Oregon.gov/DEQ.

Renewable & Low Carbon Fuel Requirements Regulation. Retrieved from www2.gov.bc.ca.

Rogoff, Kenneth. (March 2 2016). What's behind the drop in oil prices? World Economic Forum. Retrieved from weforum.org.

Rubin, J. et al. (2012.) National Low Carbon Fuel Standard Policy Design Recommendations.

Sources of Greenhouse Gas Emissions. (2017.) Retrieved from EPA.gov.

U.S. Environmental Protection Agency. (2013-2018.) Air Quality Index Report. Retrieved from EPA.gov.

Witcover, Julie. (September 2018.) Status review of California's low-carbon fuel standard, 2011-2018Q1. UC Davis: Institute of Transportation Studies.

Yeh, Sonia et al. (July 19, 2012). National Low Carbon Fuel Standard: Policy Design Recommendations. Retrieved from SSRN.com.

Yeh, Sonia et al. (2016). A review of low carbon fuel policies: Principles, program status and future directions. Energy Policy 97, pp. 220-234.

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